



Compact First-Order Probe for Spherical Near-Field Antenna Measurements at P-band

Kim, Oleksiy S.

Published in:

Proceedings of 38th Annual Meeting and Symposium of the Antenna Measurement Techniques Association

Publication date:

2016

Document Version

Peer reviewed version

[Link back to DTU Orbit](#)

Citation (APA):

Kim, O. S. (2016). Compact First-Order Probe for Spherical Near-Field Antenna Measurements at P-band. In *Proceedings of 38th Annual Meeting and Symposium of the Antenna Measurement Techniques Association* (pp. 425-427)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Compact First-Order Probe for Spherical Near-Field Antenna Measurements at P-band

Oleksiy S. Kim

Department of Electrical Engineering
Technical University of Denmark
Kgs. Lyngby, Denmark
Email: osk@elektro.dtu.dk

Abstract— A novel compact P-band dual-linearly polarized first-order probe for spherical near-field (SNF) antenna measurements is presented. The probe covers the bandwidth 421-444 MHz with more than 9 dBi directivity and parasitic $|\mu| \neq 1$ spherical modes suppressed below -35 dB. The height of the probe is just 365 mm over a 720-mm circular ground plane and it weighs less than 5 kg.

I. INTRODUCTION

A number of European Space Agency's (ESA) initiatives planned for the current decade require metrology level accuracy antenna measurements at frequencies extending from L-band to as low as 400 MHz. The BIOMASS radar, the Galileo navigation and search and rescue services could be mentioned among others. To address the needs, the Technical University of Denmark (DTU), who operates ESA's external reference laboratory "DTU-ESA Spherical Near-Field (SNF) Antenna Test Facility", developed a 0.4-1.2 GHz higher-order probe [1]. Even though the probe was fabricated of lightweight materials, aluminum and carbon-fiber-reinforced polymer (CFRP), it still weighs 22.5 kg and cannot be handled by a single person without lifting tools. Besides that, higher-order probe correction techniques are more demanding in terms of the computational complexity as well as in terms of calibration and post-processing time than the first-order probe correction.

Classical first-order probes for SNF antenna measurements utilizing conical horns fed by a circular waveguide operating in the fundamental TE₁₁-mode regime also become excessively bulky and heavy as frequency decreases, and already at 1 GHz an open-ended cylindrical waveguide probe is challengingly large. For example, the largest first-order probe at the DTU-ESA SNF Antenna Test Facility operates in the frequency band 1.4-1.65 GHz and weighs 12 kg. At 0.4 GHz, a conventional first-order probe can exceed 1 m³ in size and reach 25-30 kg in weight [2].

In this contribution, a compact P-band dual-polarized first-order probe is presented (Figure 1). The height of the probe is just 365 mm over a 720-mm circular ground plane and it weighs less than 5 kg. The probe covers the bandwidth 421-444 MHz with more than 9 dBi directivity and $|\mu| \neq 1$ modes suppressed below -35 dB. The probe has been developed under a contract with ESA.

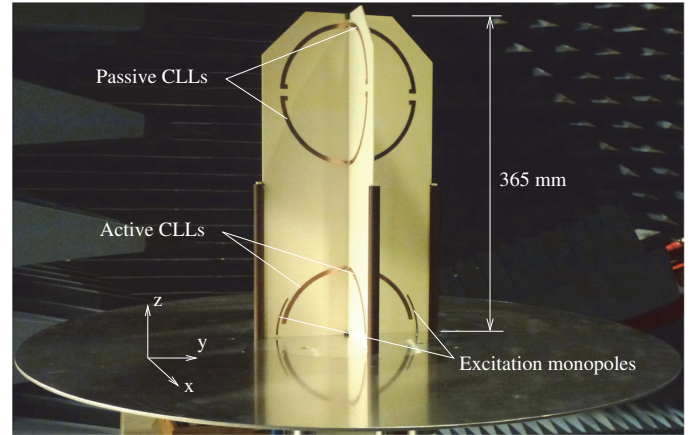


Figure 1. P-band dual-linearly polarized first-order probe.

II. REQUIREMENTS

The driving requirement for the new probe is to cover the upcoming ESA BIOMASS mission frequency range (435±3 MHz) [3], so that it is able to substitute the heavy and bulky 0.4-1.2 GHz higher-order probe [1] in BIOMASS SAR antenna measurements. First-order characteristics, dual-linear polarization, compactness and low weight are the key requirements as well.

Other specifications were set to ensure the optimal performance of the probe in the anechoic chamber of the DTU-ESA SNF Antenna Test Facility (see [4] for details):

1. Frequency 432-438 MHz
2. Peak directivity 9-14 dBi
3. Polarization dual linear
4. Radiation pattern:
 - Pattern variation within $\theta = \pm 30^\circ$ < 10 dB
 - Front-to-back ratio > 10 dB
 - Pattern symmetry: desirable in both orthogonal planes
5. First-order probe:
 - $|\mu| \neq 1$ spherical modes < -35 dB
6. Ports orthogonality > 35 dB
7. Port-to-port isolation > 35 dB
8. Return loss > 10 dB
9. Weight < 10 kg

III. ELECTRICAL DESIGN

The probe is based on a concept of a superdirective linear array of electrically small resonant magnetic dipole radiators [5]. Electrically small size of the array elements (capacitively loaded loops — CLL) ensures that they radiate essentially a dipole mode (TE₁₀ spherical mode — the lowest order $|\mu| = 1$ mode). Just two of these elements (one active and one passive) combined in a superdirective array on a circular ground plane yield the directivity above 9 dBi, which is sufficient for an SNF probe.

The probe is composed of two orthogonal linearly-polarized two-element arrays. The arrays are arranged vertically on a circular ground plane isolating them from the support structure. Each array is excited by two symmetric monopoles fed 180° out of phase, which, along with the geometrical symmetry of the structure, ensures effective suppression of even $|\mu|$ spherical modes.

The size of the array elements and the separation between them are optimized to maximize the bandwidth while keeping the strongest parasitic $|\mu| = 3$ spherical modes below the required -35 dB.

IV. MECHANICAL DESIGN AND FABRICATION

The arrays are printed on Rogers 4003C PCB substrate. This substrate was selected as the most rigid among the Rogers laminates.

Slots are cut in the middle of the boards, so that one board can slide into another at 90°. The loops split by the slots are restored by thin wire bridges fed through holes in the orthogonal PCB and soldered to the split CLLs. Two plastic fixtures center the orthogonal PCBs at the top and at the bottom.

The boards are supported by vertical Tufnol rods screwed to the ground plane by plastic screws. The rods have vertical slits in which the PCBs slide. A Tufnol disk screwed to the top of each rod fixes the PCB via a notch cut in the board's edge.

The adopted mechanical design ensures that the probe is robust and stable enough, so that its electrical characteristics do not change under rotations during the calibration and during the measurements itself.

V. MEASUREMENTS

The S-parameters were measured in an anechoic environment with a calibrated Vector Network Analyzer (VNA). The 2-port measurements directly on the probe's ports showed that the characteristics for both polarizations were nearly perfectly identical. However, characteristics of the procured Minicircuit's 180° hybrids had significant variations requiring the lengths of the coax cables connecting the hybrids to the antenna ports to be individually adjusted for each polarization. The resulting reflection coefficients plotted in Figure 2 for both polarizations are very close to each other and within the specifications. Port-to-port isolation was measured to be better than -45 dB for the entire frequency range below 446 MHz.

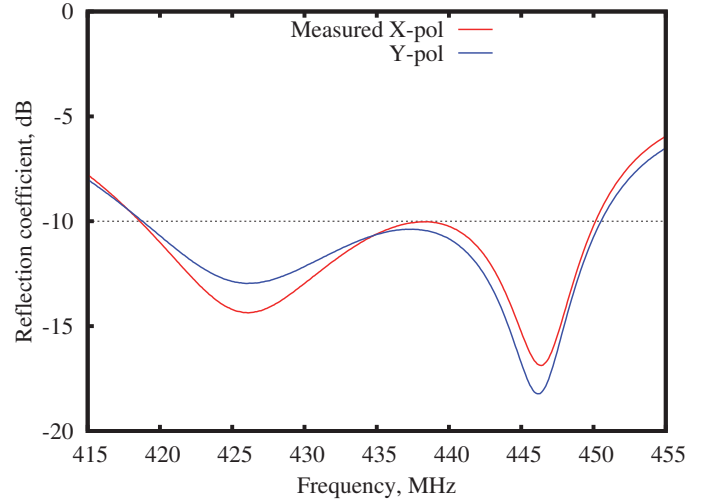


Figure 2. Measured reflection coefficient.

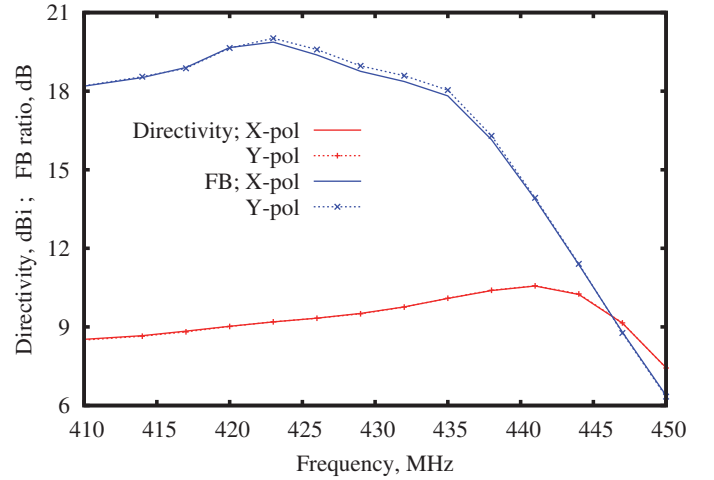


Figure 3. Measured directivity and front-to-back (FB) ratio.

The radiation characteristics were measured at the DTU-ESA Spherical Near-Field Antenna Test Facility. The full-sphere near-field measurements were carried out separately for each polarization with the 0.4-12 GHz higher-order probe [1]. The near-field data were then transformed to the far field properly taking into account characteristics of the higher-order probe via a higher-order probe correction [6].

The radiation characteristics for both polarizations are nearly perfectly identical, as observed in Figure 3, where the maximum directivity and front-to-back (FB) ratio (a ratio between the directivity and the maximum back radiation in the angular range $120^\circ \leq \theta \leq 180^\circ$) are plotted versus frequency, as well as in Figure 4 showing measured radiation patterns for X- and Y-polarization at 435 MHz.

The spherical mode spectrum (Figure 5) computed from the measured data exhibits the dominating $|\mu| = 1$ modes with parasitic $|\mu| \neq 1$ modes suppressed below -40 dB. These are characteristics of a good quality first-order probe.

The useful bandwidth is 421-444 MHz; it is limited by the directivity at the lower end and by the FB ratio at the higher end. If somewhat lower directivity (for example, 8.5 dBi) and

higher reflection coefficient (for example, -6 dB) are accepted, the probe can then be used down to 411 MHz, since its pattern is still symmetric and has excellent first-order characteristics at those frequencies.

VI. CONCLUSION

A novel P-band dual-linearly polarized first-order probe for SNF antenna measurements has been designed, manufactured, and tested. The probe is based on a superdirective linear array of electrically small resonant magnetic dipole radiators, which has proven to be a compact, light-weight and cost-effective alternative to open-ended cylindrical waveguides and conical horns when used as a first-order probe for SNF measurements at frequencies below 1 GHz. Even though, the attained fractional bandwidth is about 5%, which is twice narrower than that of a typical cylindrical waveguide probe, the new probe is by far superior in terms of ease of fabrication and handling.

REFERENCES

- [1] O. S. Kim, S. Pivnenko, and O. Breinbjerg, "0.4-1.2 GHz hybrid Al-CFRP open-boundary quad-ridge horn," in Proc. 33rd ESA Antenna Workshop, ESTEC, Noordwijk, the Netherlands, 18-21 October 2011.
- [2] Reiche, Enrico, *et al.* "A dual linear high performance UHF probe antenna for test ranges." in Proc. 30th ESA Antenna Workshop, 2008.
- [3] F. Heliere, F. Fois, M. Arcioni, P. Bensì, M. Fehringier, and K. Scipal, "BIOMASS P-band SAR interferometric mission selected as 7th earth explorer mission," in Proc. 10th European Conf. Synthetic Aperture Radar EUSAR 2014, June 2014, pp. 1-4.
- [4] O. S. Kim, S. Pivnenko, and O. Breinbjerg, "Wideband scalable probe for spherical near-field antenna measurements," in Proc. 5th European Conference on Antennas and Propagation (EuCAP'2011), Rome, Italy, 2011, pp. 1781-1785.
- [5] O. S. Kim, S. Pivnenko, and O. Breinbjerg, "Superdirective magnetic dipole array as a first-order probe for spherical near-field antenna measurements," IEEE Trans. Antennas Propag., vol. 60, no. 10, pp. 4670-4676, 2012.
- [6] T. Laitinen, S. Pivnenko, J. M. Nielsen, and O. Breinbjerg, "Theory and practice of the FFT/matrix inversion technique for probe-corrected spherical near-field antenna measurements with high-order probes," IEEE Trans. Antennas Propag., vol. 58, no. 8, pp. 2623-2631, 2010.

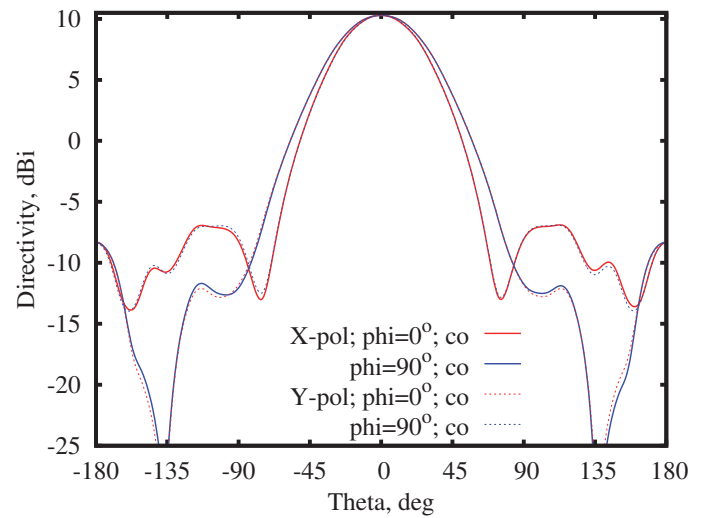


Figure 4. Measured radiation pattern at 435 MHz.

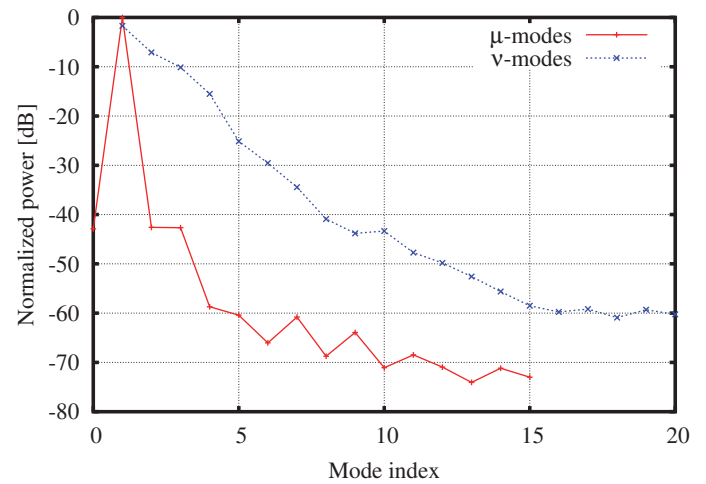


Figure 5. Spherical mode spectrum at 435 MHz.